

# SN 1987A – 20 Years After: Supernovae & Gamma-ray Bursts

The SN 1987A Link to  
Gamma-ray Bursts

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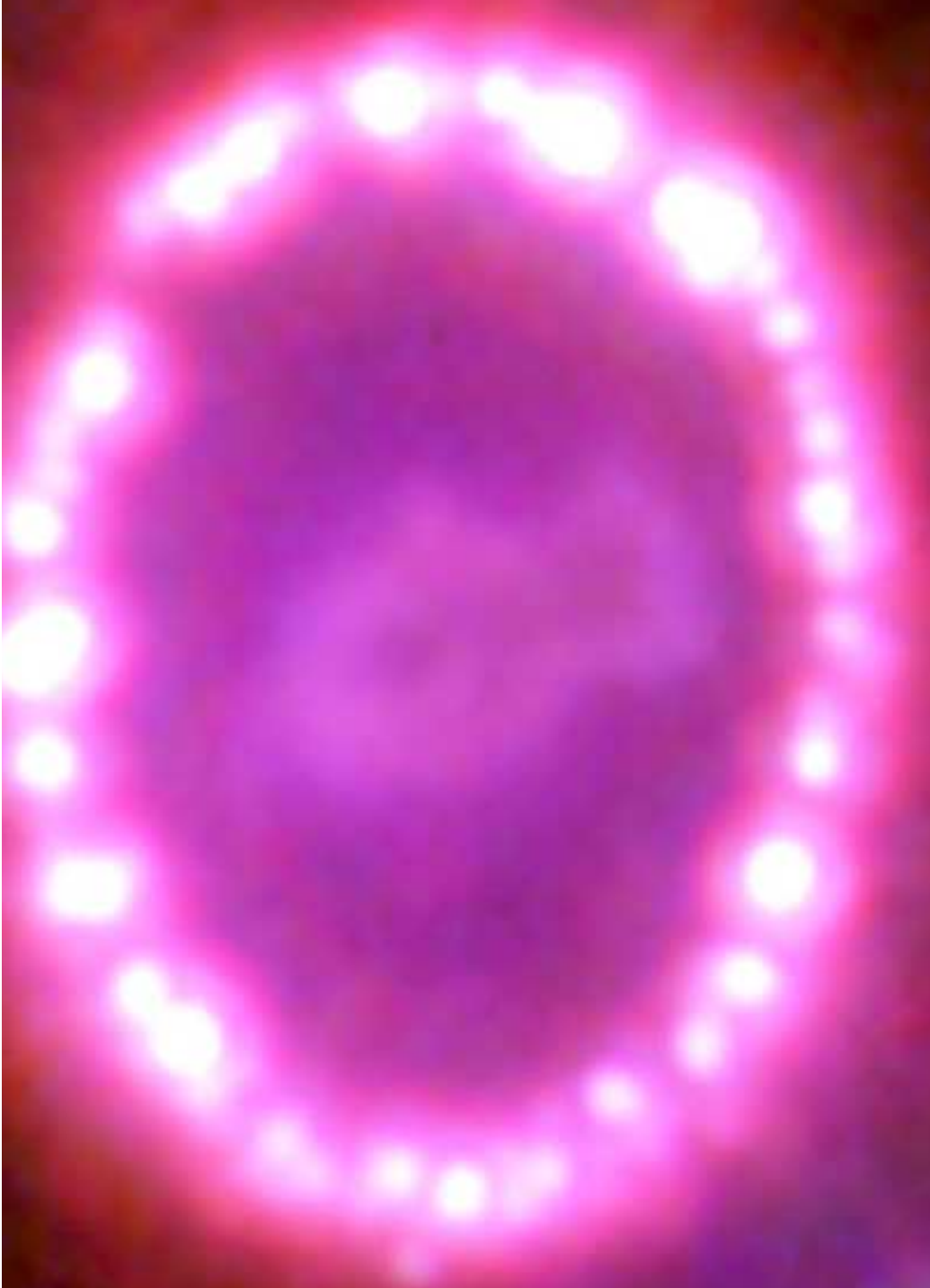


Fig. 1.— SN 1987A as of December 2006, as viewed with the HST (NASA, P. Challis, & R. Kirshner, Harvard-Smithsonian Center for Astrophysics). The bipolarity of the explosion is suggestive of (electron) degenerate core-core merger-induced core-collapse.

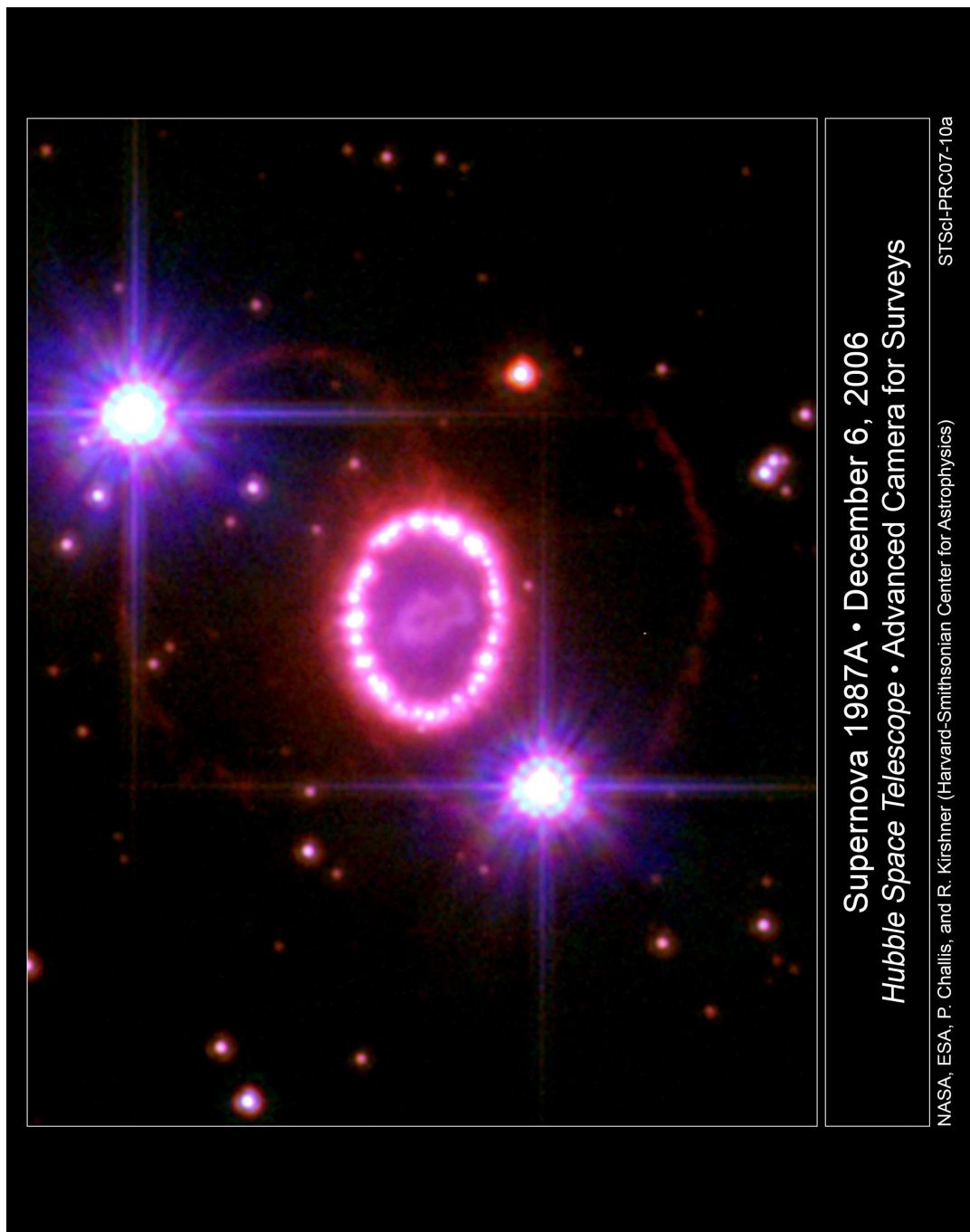


Fig. 2.— The whole field of Figure 1, showing nearby stars and the outer rings. The details of the three rings also suggest merger-induced core-collapse as the cause of SN 1987A.

1987ApJ...320L..15N

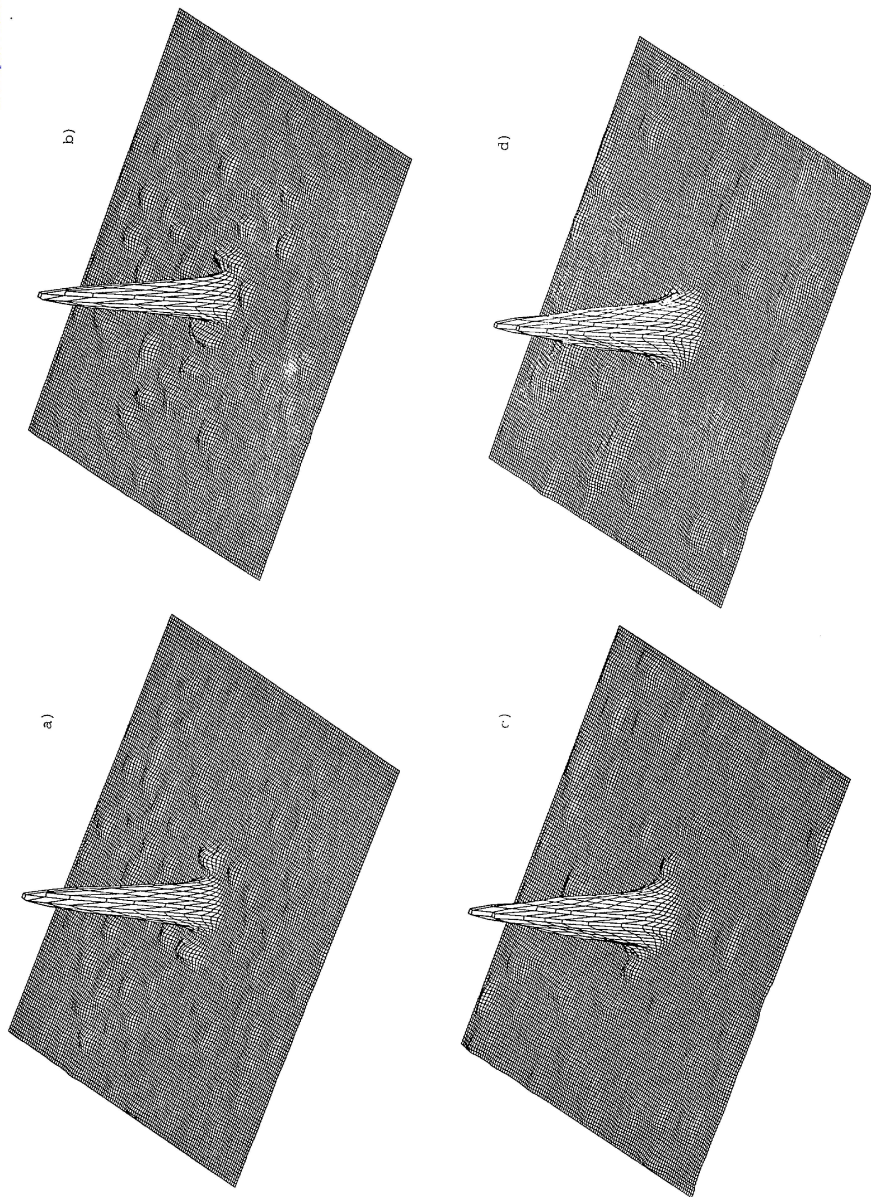


FIG. 2.—Speckle autocorrelation images of the region around SN 1987A in three wavelengths and a comparison star. (a) Autocorrelation in H $\alpha$ . (b) Autocorrelation at 533 nm. (c) Autocorrelation at 450 nm. (d) Autocorrelation of the reference star  $\nu$  Doradus at 450 nm.

Fig. 3.— From Nisenson et al. 1987, ApJ, 320, L15, the “Mystery Spot” and comparison star,  $\nu$  Doradus. This feature was seen 30, 38 and 50 days *after* core-collapse, and the associated energy was  $10^{49}$  ergs, of which some 3% was radiated into the optical.

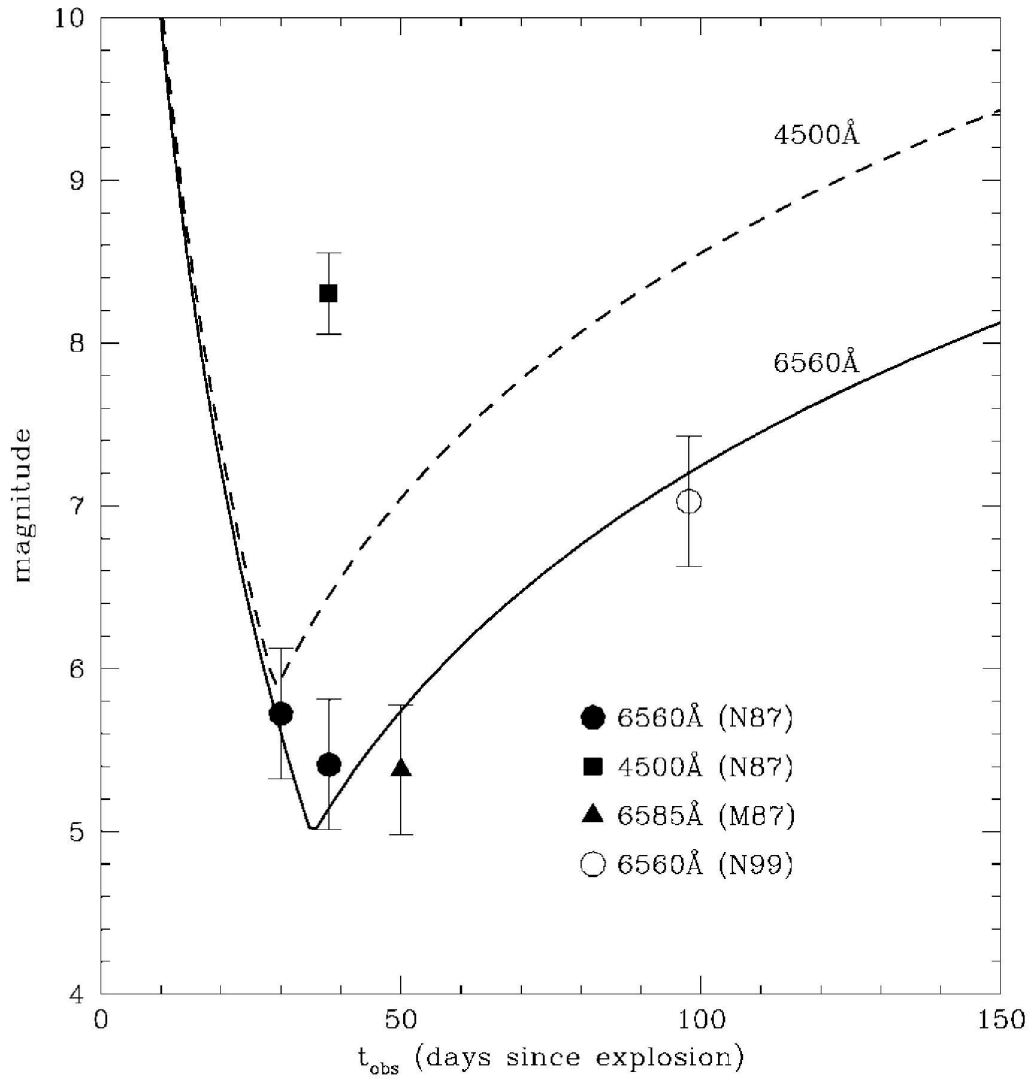


Fig. 4.— From Cen, R. 1999, ApJ, 524, L51, the luminosity of the “Mystery Spot” vs time, modeled as a lateral gamma-ray burst.

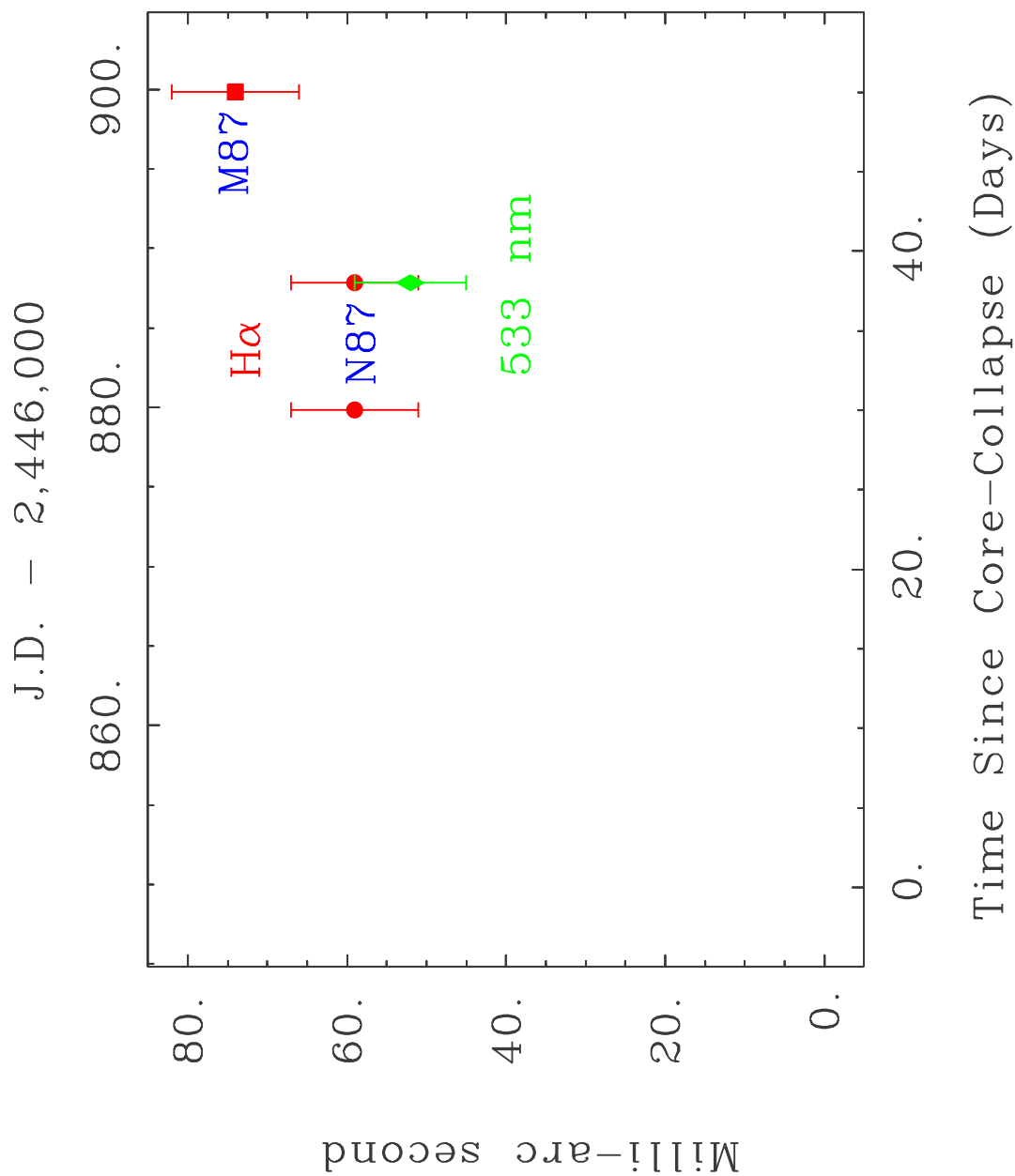


Fig. 5.— Measurements of displacement of the “Mystery Spot” at H $\alpha$  and 533 nm, vs time, from Nisenson et al. 1987, ApJ, 320, L15 (N87), and Meikle et al. 1987, Nature, 329 608 (M87).

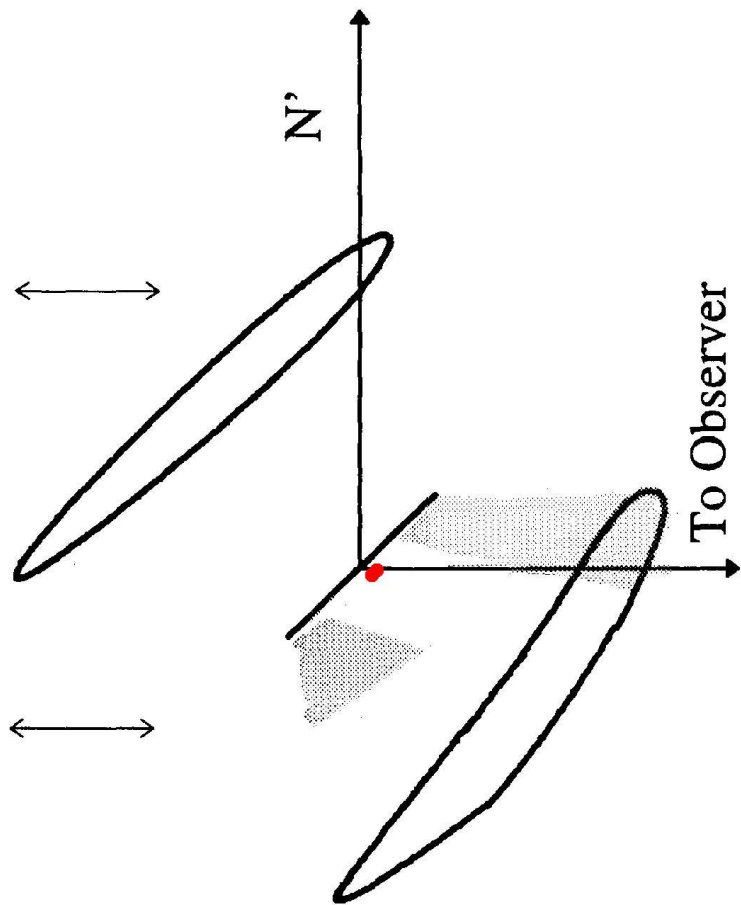


FIG. 3.—Geometry for the three rings that is consistent with the new ages, and light-travel time constraints. Hypothetical sources for the ended emission seen in the images are also marked.

Fig. 6.— From Burrows et al. 2006, ApJ, 452, 680, the geometry of the “Mystery Spot,” (MS - in red), and rings.

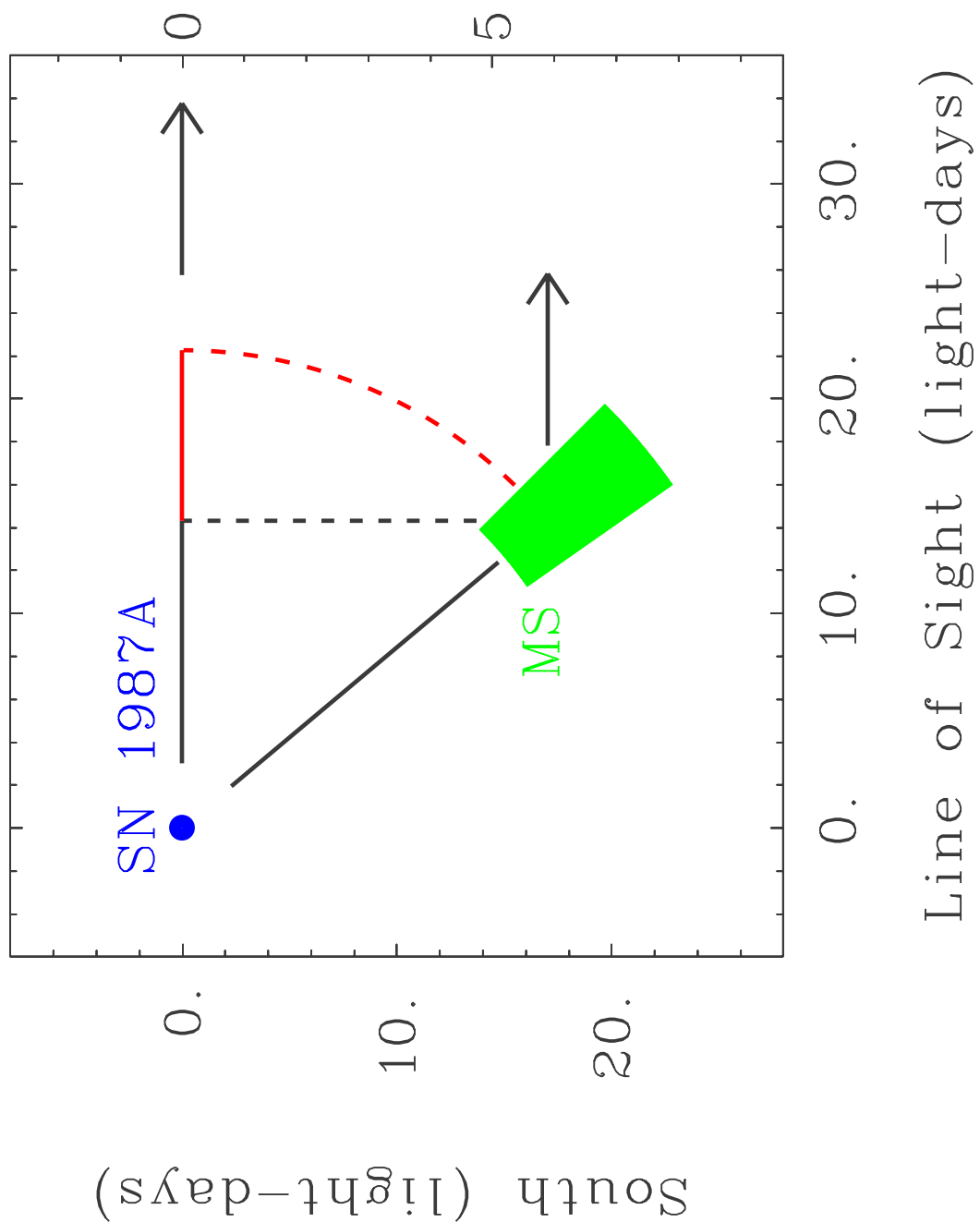


Fig. 7.— The geometry of the “Mystery Spot,” (MS) associated beam, and direct line of sight from SN 1987A. It takes an extra *eight* days for light from 87A to hit the MS and proceed on to the Earth. The distance from 87A to the MS is some 22 light-days.





Fig. 8.— The globular cluster (GC), M28 (photo: Bernd Flach-Wilken, Volker Wendel, [spiegelteam.de](http://spiegelteam.de)), which lies in the plane of the Galaxy, and in which the first millisecond pulsar, B1824-21, with a period of 3 ms was discovered. Many, many more followed, far, far too many to have been spun up by “recycling” through an X-ray binary, suggesting merger-induced core-collapse as the source of the millisecond pulsars in the non-core-collapsed GCs.



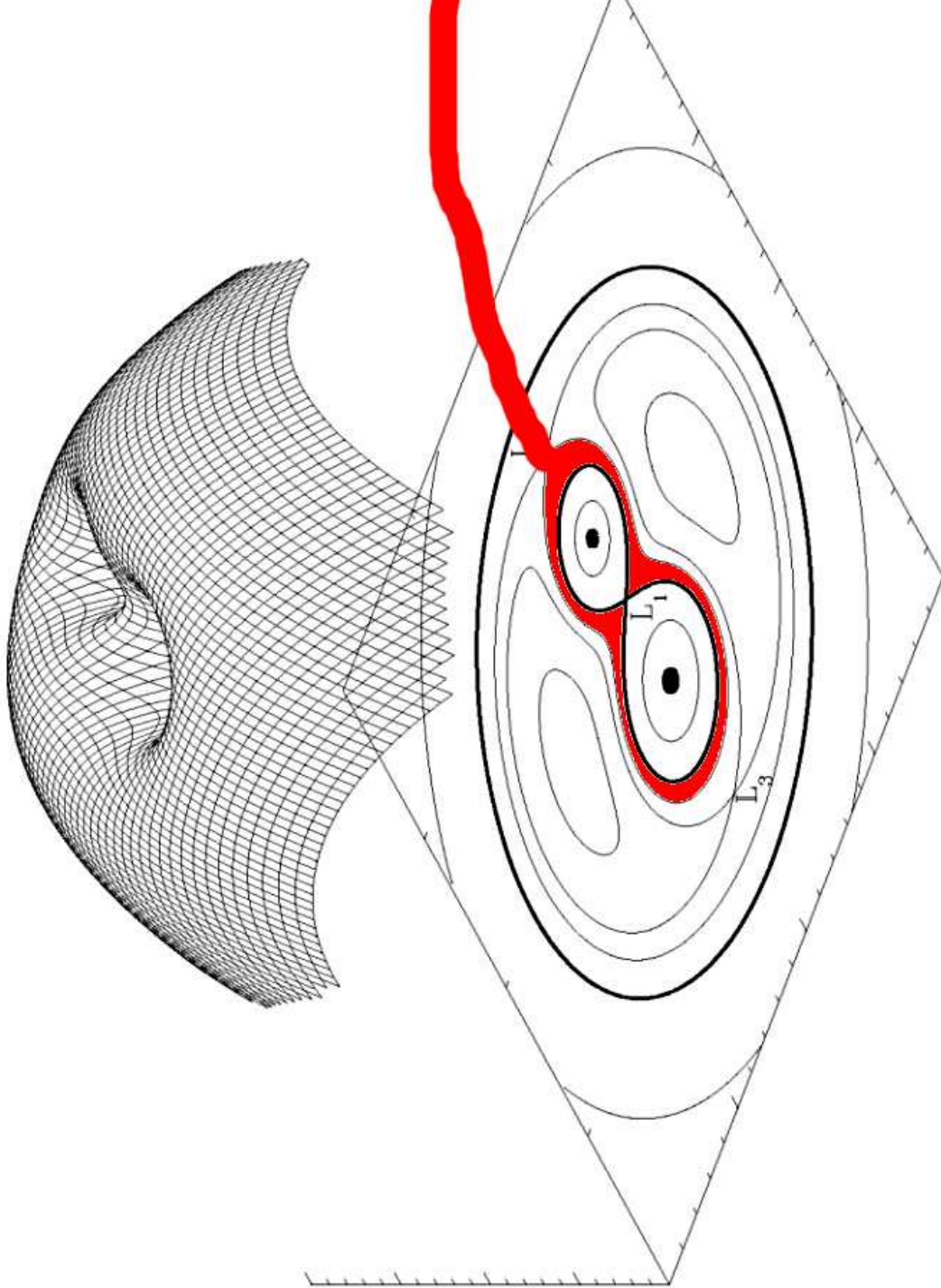


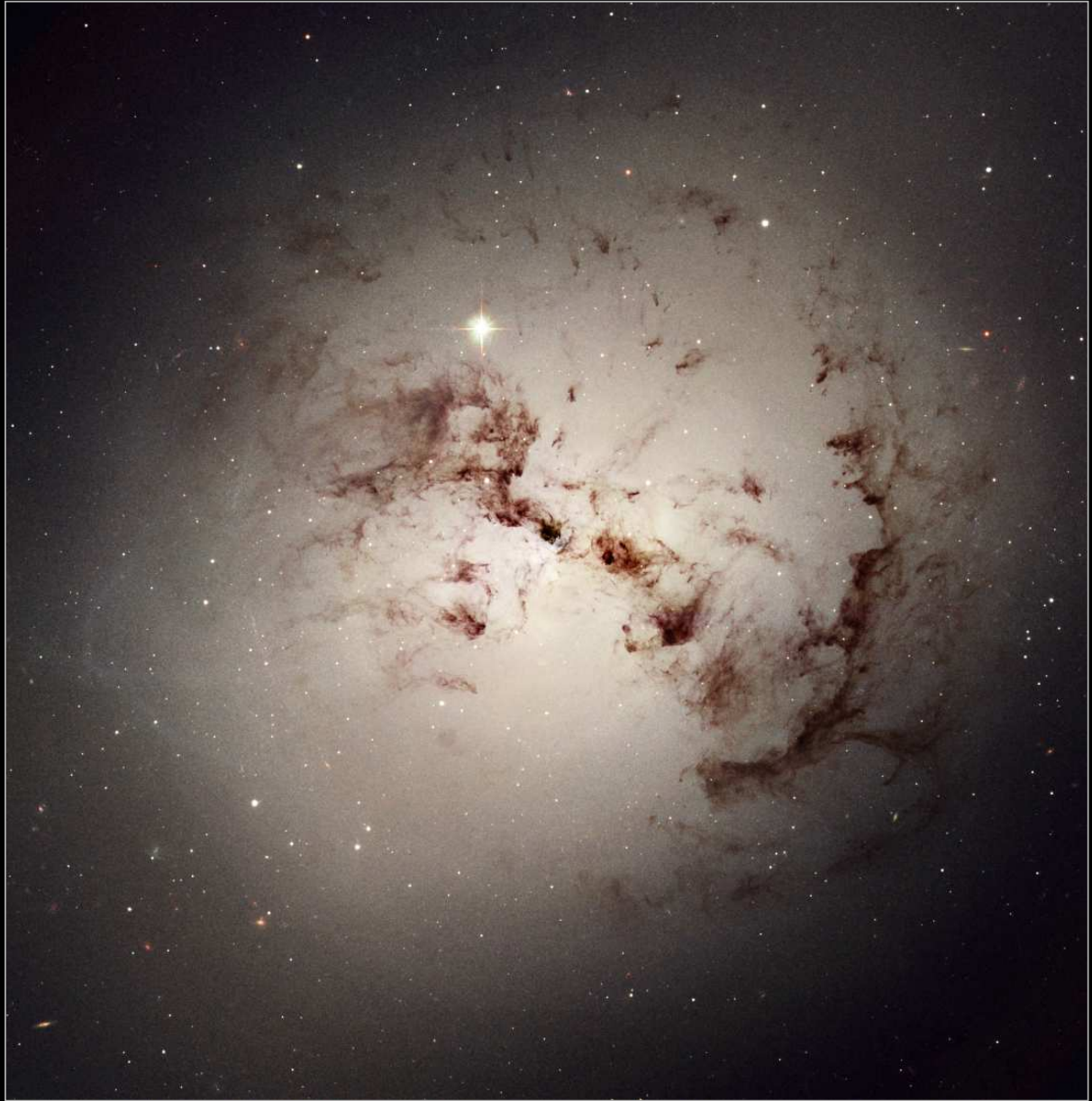
Fig. 9.— SN 1987A was very likely to have been the result of a binary merger. From [http://en.wikipedia.org/wiki/Roche\\_lobe](http://en.wikipedia.org/wiki/Roche_lobe), gas (red) spills from the common envelope through the mass-axis Lagrangean point nearest to the smaller mass,  $L_2$  (partially obliterated) with the astrophysically negligible velocity of  $10 \text{ km s}^{-1}$  (the thermal velocity of H at 10,000 K). The two stars occupy the two holes of the potential perpendicular to the binary plane. Radiation pressure alone would drive gas off the rotation axis by  $45^\circ$ , but it is also driven off dynamically as shown in Morris and Podsiadlowski (2007 *Science*, 315, 1103).

## Nine Reasons Why Ia SN Aren't Single Degenerate

1. Hydrogen
1. Helium
3. High Velocity Features
4. Polarization  $\propto 1./\text{Luminosity}$
5. No Ia Radio SNe
6. NGC 1316 – 4 Ia's/26 Years
7.  $>1.2 M_{\odot} {}^5{}^6\text{Ni}$  (2003fg)
8. CVs are explosive
9. Need Core–Collapse for Zn

Fig. 10.— A list of reasons why Type Ia SNe can not be single degenerate, i.e., the thermonuclear disruption of a white dwarf slowly accreting He and/or H from a non-degenerate companion until it reaches the Chandrasekhar mass ( $1.4 M_{\odot}$ ). Reason number 5 is from Panagia et al. 2006, ApJ, 646, 369, and K. Weiler's talk at this conference.

## Elliptical Galaxy NGC 1316



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Fig. 11.— The merging elliptical and spiral galaxies of NGC 1316. Four, count ‘em, *four* Type Ia SNe in 26 years, again suggesting merger-induced etc. “And the single degenerate model for Ia’s lies on the floor, shattered into pieces.”



Fig. 12.— SN 2006dd and 2006mr (0W 16N, and 16E 0N) simultaneously visible in the merging elliptical and spiral galaxies of NGC 1316 (from Immler, Gehrels, & Nousek <http://www.science.psu.edu/alert/Swift11-2006.htm>). The last time this happened was after 1981, March 16, for 1980N and 1981D (220E 20S, and 20W 100S).

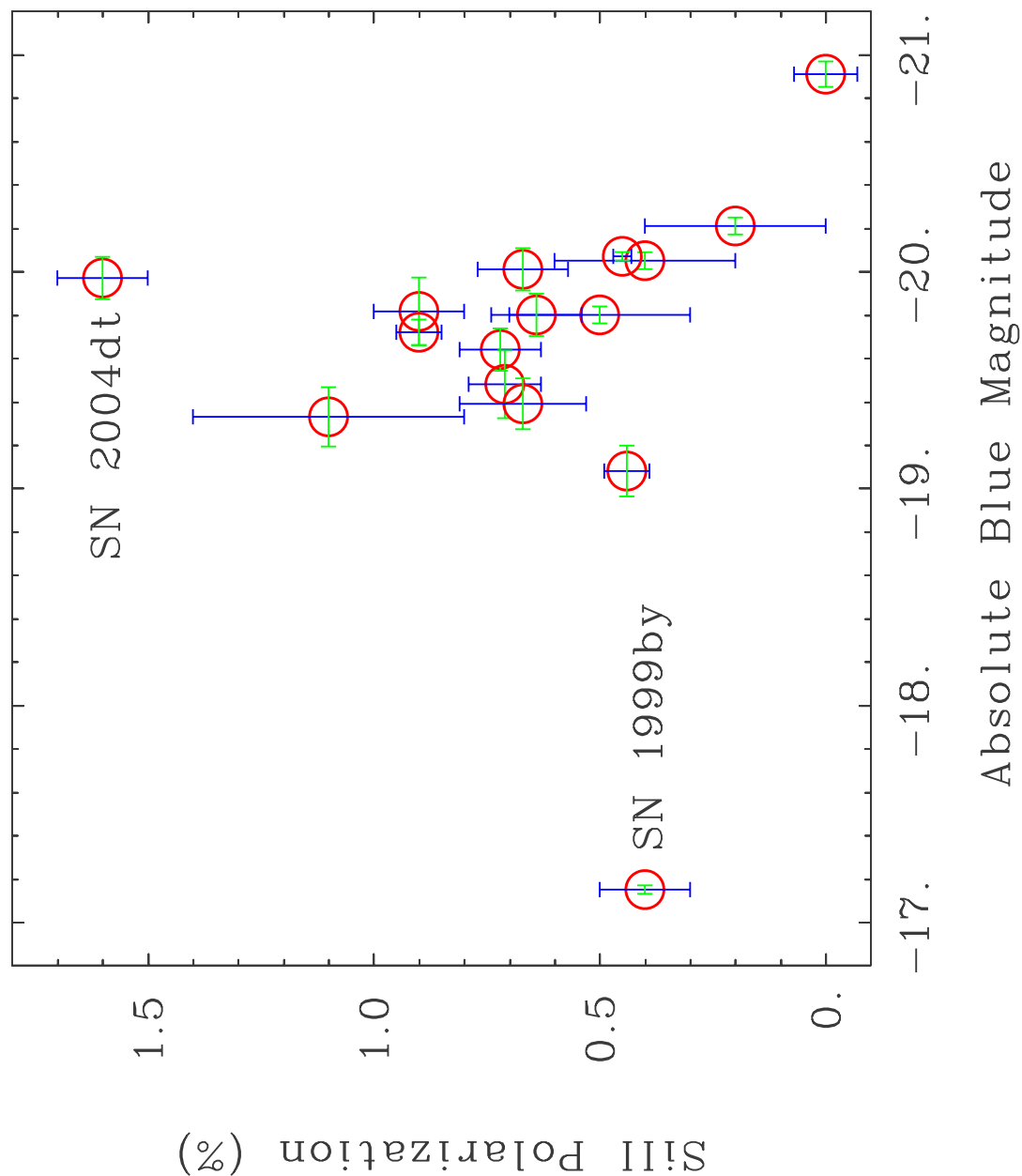


Fig. 13.— After Wang et al. 2007, Science, 315, 212, the inverse relation of SiII polarization in Type Ia supernovae vs luminosity, just one of the many reasons why Ia’s can not be single degenerate. Absolute magnitudes were calculated as  $1.95278 \times \Delta m(B)_{15} - 22.335$ , except for SNe 1999by, 2004eo, and 2005cf, which had measured values.



Fig. 14.— From <http://www.answers.com/topic/cataclysmic-variable-star>, a depiction of a cataclysmic variable – the fantasy long held by many that these are the progenitors of Type Ia SNe (and don’t periodically explode as CV’s do because the accreting material supposedly burns as it hits the white dwarf star, shown in the center of the accretion disk, due to an accretion rate favorable to the “instant burning” hypothesis). Observations have shown otherwise, one of the points of this talk.

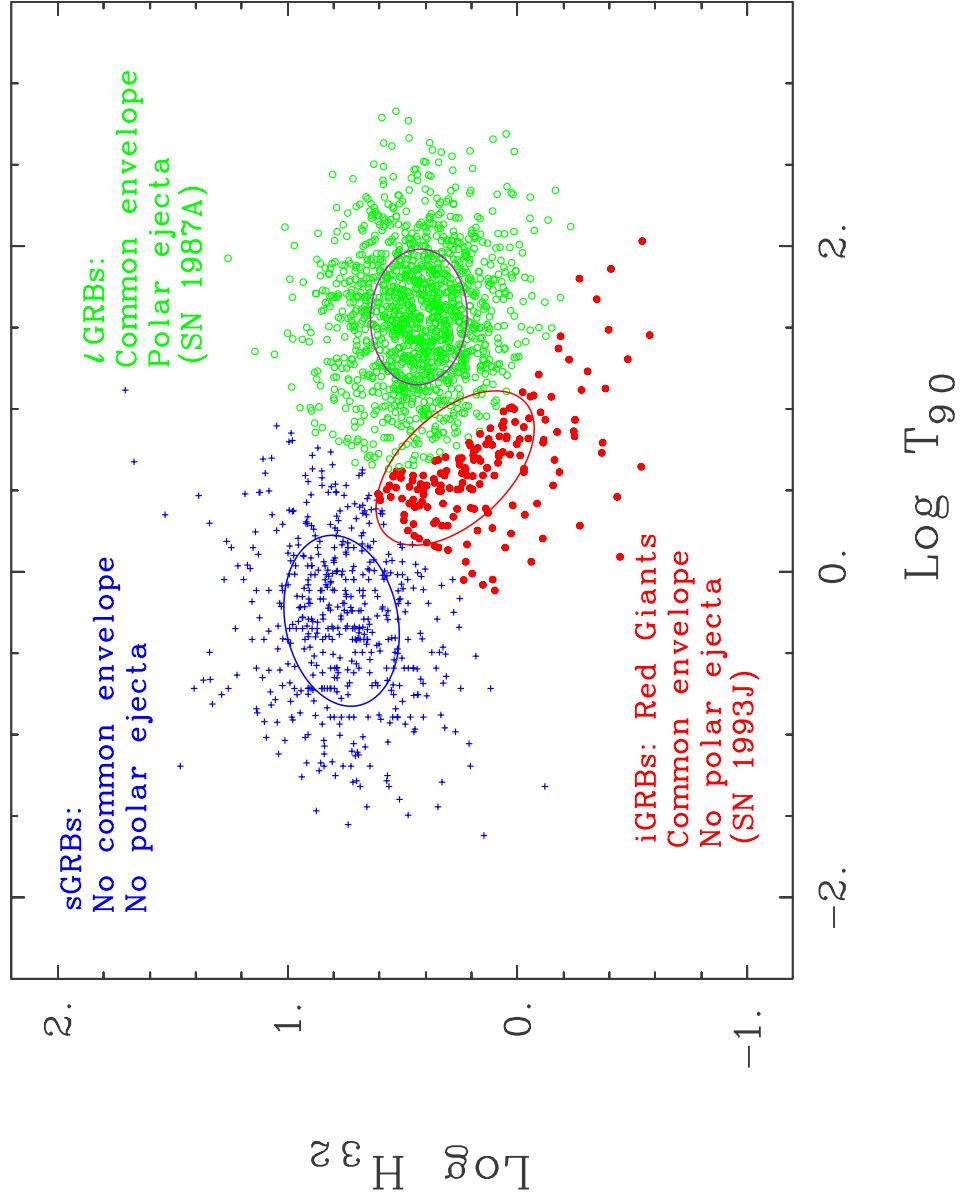


Fig. 15.— After Horváth et al. 2006, A&A, 447, 23, the GRBs from the BATSE catalog (Meegan, C. A., et al. 2001, <http://gamma-ray.msfc.nasa.gov/batse/grb/catalog/>) are scattered in duration ( $T_{90}$ )-hardness ( $H_{32}$ ) space. The new third region may be characteristic of merger-induced red supergiant core-collapse, as the early polarization of SN 1993J was *twice* that of SN 1987A. There are no short, hard (s)GRBs (blue ‘+’s) in elliptical galaxies, yet we know that WD-WD (core-core) merger (DD), as in SN 1987A, makes, or tries to make GRBs, and dominates all other mechanisms (as always through binary-binary collision), such as NS-NS merger, even when requiring enough mass to produce core-collapse. Thus most of the sGRBs in ellipticals are due to DD, but without having to pass through common envelope and/or polar ejecta, the means by which they *become* long, soft lGRBs (small green circles), or intermediately long, softest iGRBs (red disks).



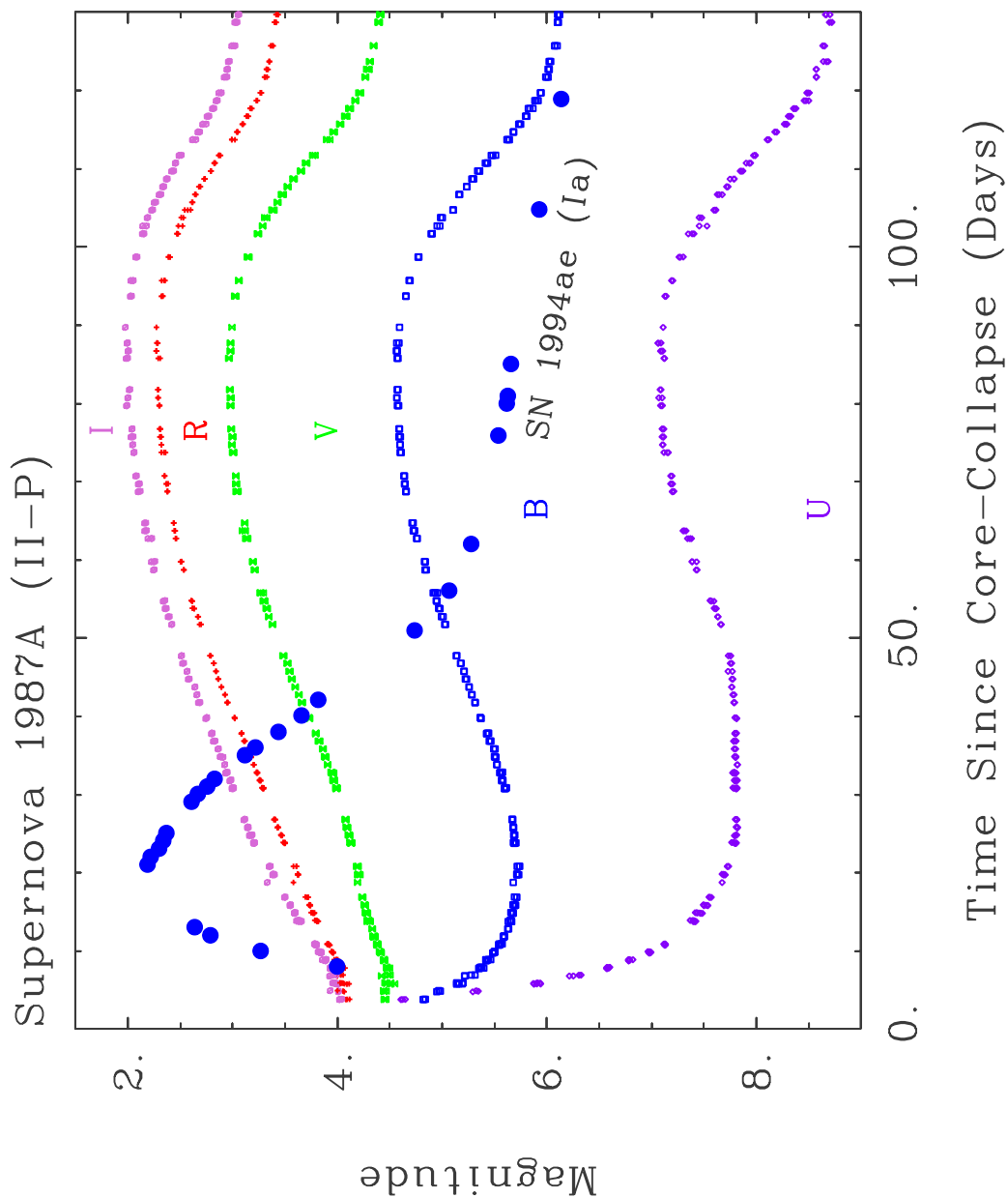


Fig. 16.— The early light curve (luminosity history) of SN 1987A from Cerro Tololo Inter-American Observatory (Hamuy & Suntzeff 1990, AJ, 99, 1146, in the five bands, U, B, V, R, and I, for the first 130 days following core-collapse, and the B light curve from the Type Ia SN 1994ae (filled circles – from Riess et al. 1999, AJ, 117, 707), offset by -11 mag.

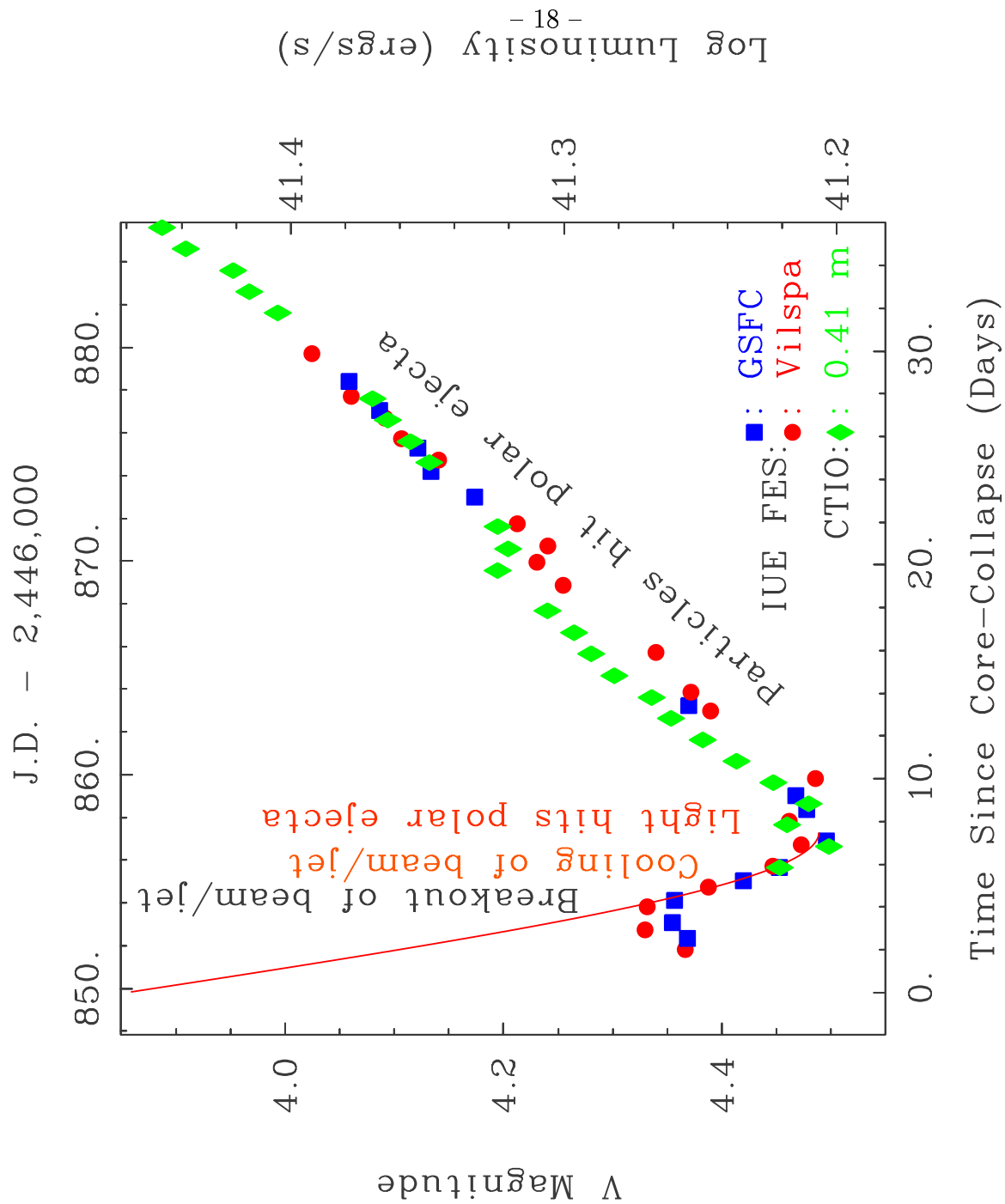


Fig. 17.— After Wamsteker et al. 1987, A&A, 177 L21 the very early luminosity history of SN 1987A as observed with the Fine Error Sensor of IUE. Data points taken at Goddard Space Flight Center by Sonneborn & Kirshner, and the Villafranca Station in Madrid, Spain, are marked. Various stages of beam/jet breakout and interaction with polar ejecta are labeled. The fit to the six points from day 854.5 to 857 is a parabola, consistent with optically thin thermal radiative cooling. The decrement near day 20 is actually preceded by a *spike* with strange colors (B, R, & I, but little U or V – see the previous viewgraph – a reverse shock? pulsar?).

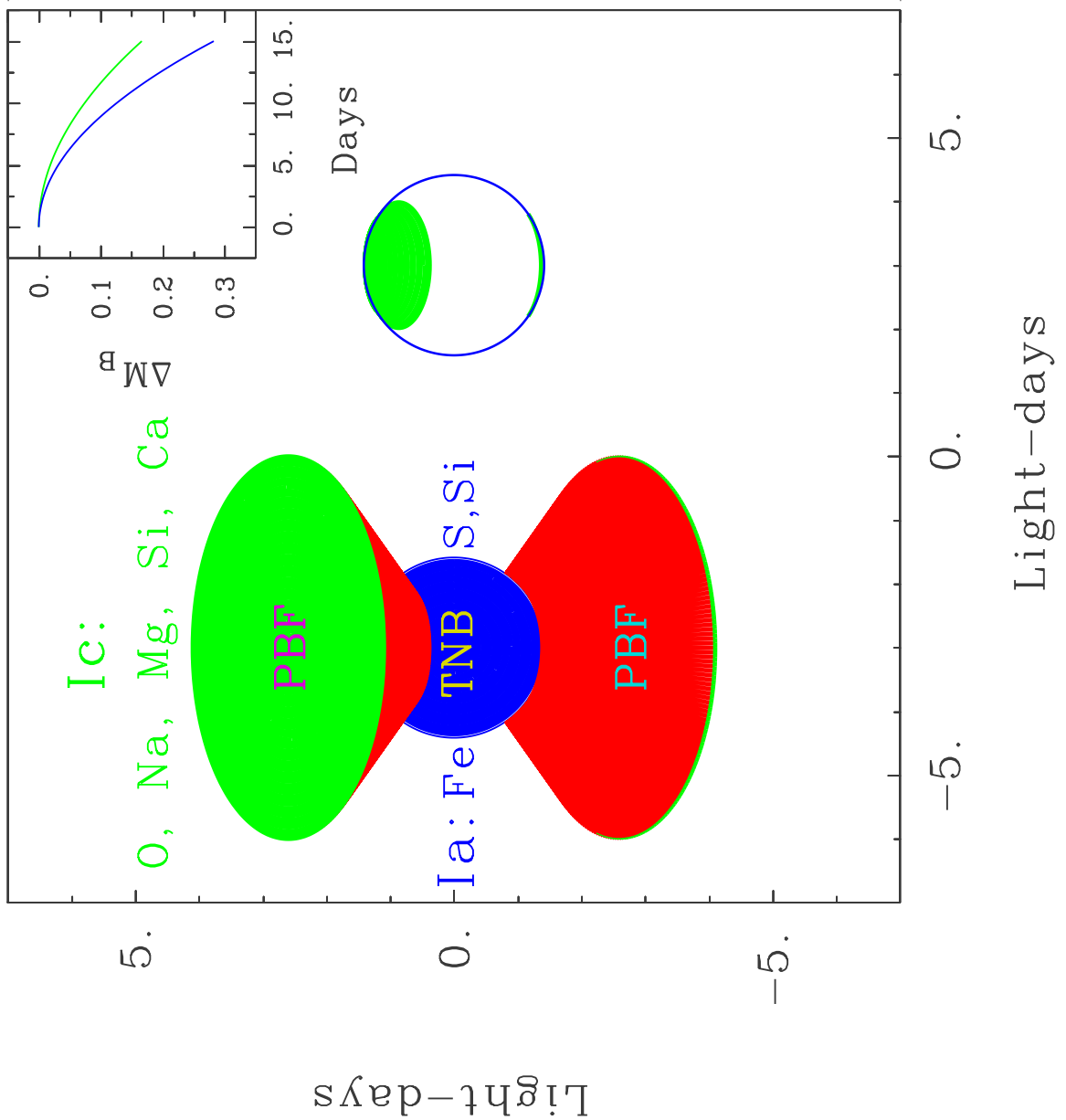


Fig. 18.— The geometry for Type Ia SNe, as viewed  $30^\circ$  off the merger equator. The thermonuclear ball (TNB), whose luminosity is dominated by the decay of  $^{56}\text{Ni}$ , is shown in blue, while the polar blowout features (PBFs), each with a half angle of  $45^\circ$ , are sketched as cones in red on the left. Systematics can occur because there is less material to be ejected in Ia PBFs than in those of Type II SNe such as 1987A, and as a consequence the Ia PBFs are ejected with a higher velocity, possibly exposing the PBF footprint on the TNB shown in green on the right, during the interval when  $\Delta m_{15}$  is measured (see inset at upper right – the curves are for an intrinsic  $\Delta m_{15}$  of 0.5 mag, and views of  $0^\circ$  [blue] and  $30^\circ$  [green] off the merger equator). If TNBs start out as toroids, as seems likely, the difference between the green and blue curves could easily be twice as large, accounting for the full effect in Ia cosmology. Also, as drawn, Ia’s viewed pole-on are Ic’s, given sufficient matter in the overlayer. Otherwise, it would just beg the question of what Ia’s viewed from the poles *would* look like.

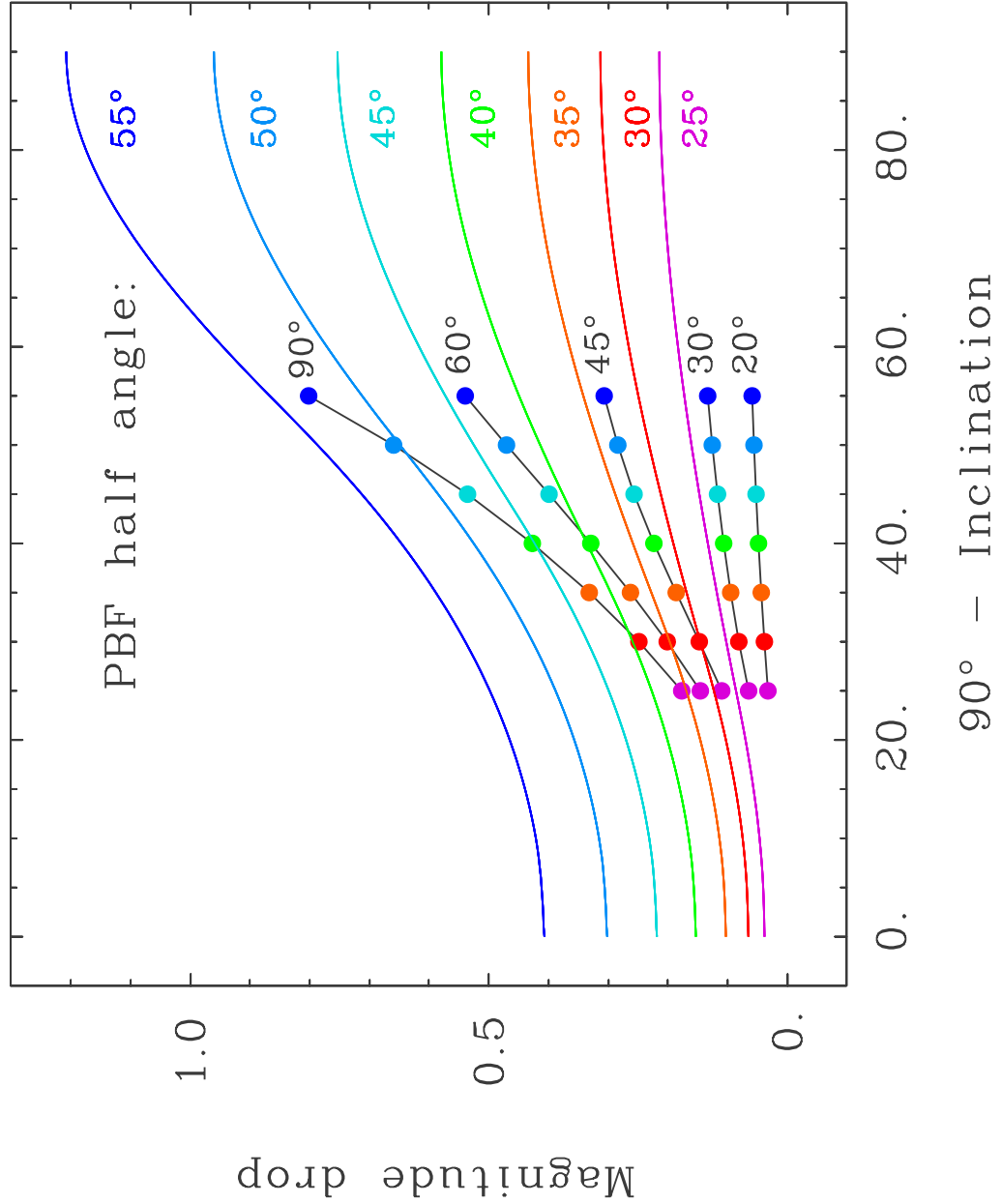


Fig. 19.— The maximum drop in magnitude from exposure of the PBF footprint(s) to an observer as a function of inclination for PBF half angles of 25-55°, assuming no contribution to the change in luminosity from the PBFs themselves. The curves with disks represent the *changes* in the drops in magnitude between the co-inclination labelled at their right hand ends, and the drops at 0° co-inclination, and the points are plotted on the abscissa at the co-inclinations of their PBFs.

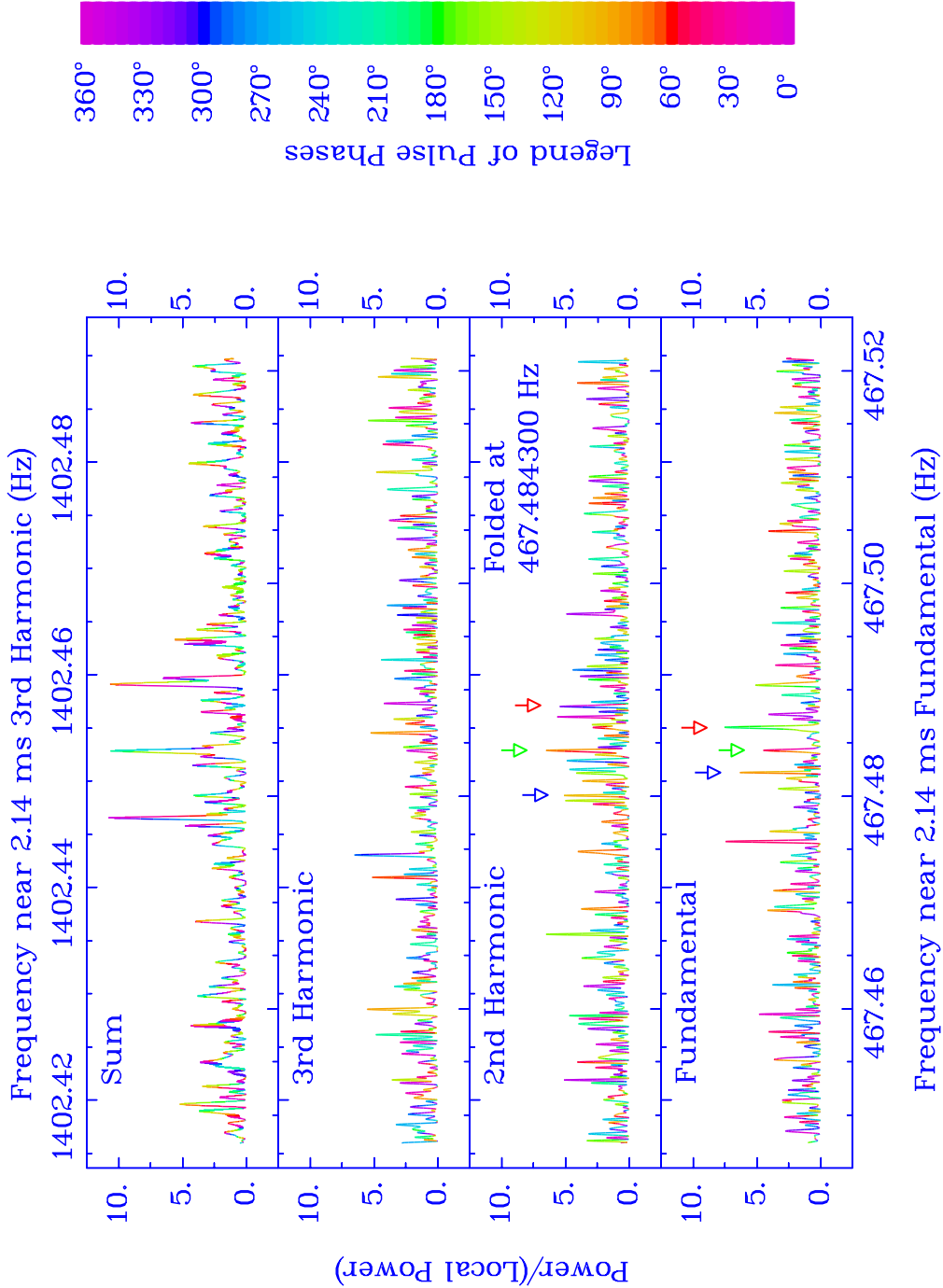


Fig. 20.— (Lower three frames) The Fourier power spectra from SN 1987A for frequency regions near 467.4843 Hz (close to the Feb. '92 467.4934 Hz frequency extrapolated to Feb. '93) and its first two higher harmonics (the 2nd near 935 Hz and the 3rd near 1402.5 Hz) from data taken at Las Campanas Observatory during early UT Feb. 6, '93. (Top frame) The sum spectrum of the fundamental and 2nd harmonic. The arrows point out the peaks in the fundamental and 2nd harmonic spectra which sum to the three high peaks in the top frame. With confirmation from the first three results from the University of Tasmania 1-m telescope in the following months, this result is likely to hold up (better get used to it), and there is every reason to think that 2 ms pulsars are the *generic* result of WD-WD merger.

# Conclusions

SN 1987A was caused by a merger of two stellar cores, and is the Rosetta Stone for 99% of SNe, including all in the modern era except SN 1986J, & the Rosetta Stone for 99% of gamma-ray bursts (GRBs).

Like SN 1987A, Type Ia SNe are due to mergers of stellar cores, and when observed from their merger poles will be classified as Type Ic's, if sufficient matter exists in the layer above core-collapse to hide the thermonuclear ashes of Fe, S, and Si.

The initial photon spectrum of all GRBs except those from SGRs is known.

There is no need to invent collapsars, hypernovae, supranovae, or super-Chandrasekhar mass white dwarfs.